LOCAL NETWORK ROUTER AND METHOD OF ROUTING IP DATA PACKETS

Field of the Invention

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This invention relates in general to routing methods, in particular to IP routing and more particularly to routing data packets in a home or office and through systems that provide two-way data

10   communications over cable television networks.

Background of the Invention

Cable television networks provide cable

15   television services to a large number of subscribers over a large geographical area. The cable television networks typically are interconnected by cables such as coaxial cables or a Hybrid Fiber/Coaxial ("HFC") cable system which have data rates of about 10 Mega-bits-per-

20   second ("Mbps") to 30 + Mbps or greater. The Internet, a world-wide-network of interconnected computers, provides multi-media content including audio, video, graphics and text that typically requires a large bandwidth for downloading and viewing. Most Internet

25   Service Providers ("ISPs") allow customers to connect to the Internet via a serial telephone line from a Public Switched Telephone Network ("PSTN") at data rates including 14,400 bps, 28,800 bps, 33,600 bps, 56,000 bps and others that are much slower than the

30   about 10 Mbps to 30 + Mbps or greater available on a coaxial cable or HFC cable system on a cable television network.

With the explosive growth of the Internet, many customers have desired to use the larger bandwidth of a

cable television network to connect to the Internet and other computer networks. Cable modems offer customers higher-speed connectivity to the Internet, an intranet, Local Area Networks ("LANs") and other computer

5 networks via cable television networks. These cable modems currently support a data connection to the Internet and other computer networks via a cable television network with a data rate of up to 30 + Mbps or greater, which is a much larger data rate than can

10 be supported by a modem used over a serial telephone line.

Many cable television networks now provide two-way or bi-directional cable systems, supporting both a downstream and upstream data path. A downstream data

15 path is the flow of data from a cable system headend to a customer. A cable system headend is a central location in the cable television network that is responsible for sending cable signals in the downstream direction. A return data path via an out-of-band

20 channel is typically used for an upstream data path. An upstream data path is the flow of data from the customer back to the cable system headend.

An exemplary data-over-cable system includes customer premise equipment (CPE) (e.g., a customer

25 computer), a cable modem, a cable modem termination system, a cable television network, and a data network (e.g., the Internet).

The cable modem termination system receives data packets from the data network and transmits them

30 downstream via the cable television network to a cable modem attached to the CPE. In a two-way cable system, the CPE sends response data packets to the cable modem, which sends the data packets upstream via the cable television network to the cable modem termination

system. The cable modem termination system sends the response data packets back to the appropriate host on the data network.

5   As a cable modem is initialized in a data-over-cable system, it registers with a cable modem termination system to allow the cable modem to receive data over a cable television connection and from a data network (e.g., the Internet or an Intranet). The cable modem forwards configuration information it receives in
10   a configuration file during initialization to the cable modem termination system as part of a registration request message. A cable modem also helps initialize and register any attached CPE with the cable modem termination system.

15   A cable modem termination system in a data-over-cable system typically manages connections to tens of thousands of cable modems. Most of the cable modems are attached to host CPE such as a customer computer. To send and receive data to and from a computer network
20   like the Internet or an intranet, a cable modem and CPE and other network devices have a network address dynamically assigned on the data-over-cable system. Many data-over-cable systems in the prior art use a Dynamic Host Configuration Protocol ("DHCP") as a
25   standard messaging protocol to dynamically allocate network addresses such as Internet Protocol ("IP") addresses. As is known in the art, the Dynamic Host Configuration Protocol is a protocol for passing configuration information to network devices on a
30   network. The Internet Protocol is an addressing protocol designed to route traffic within a network or between networks.

        As a cable modem is initialized, it will obtain a network address such as an Internet Protocol address

(e.g., with a Dynamic Host Configuration Protocol) and send the network address to the cable modem termination system. The cable modem termination system stores the network address for the cable modem in an internal

5   table.   When CPE attached to a cable modem is initialized, it will also obtain a network address such as an Internet Protocol address. The network address for the CPE is stored in an internal table on the cable modem.   The network address for the CPE is also stored

10 on the cable modem termination system with a network address for a cable modem the CPE is associated with. When data arrives for the CPE from a network like the Internet or an intranet, the cable modem termination system uses the internal tables to route the data to

15 the CPE. A network address from the data will be used to compare with network addresses from the internal tables on the cable modem termination system. The cable modem termination system will look up a network address from the data and determine that it is for CPE. Since

20 the cable modem termination does not have direct connections to CPE, it will send the data to a cable modem associated with the CPE.   The network address for the cable modem is determined from an internal table on the cable modem termination system that associates a

25 cable modem with a CPE.

In many cases, there are several pieces of CPE at, for example, a home location that may communicate through a single cable modem through a broadband two-way cable network.   Each CPE may communicate with a

30 different ISP to reach the internet and communication with other network equipment, including the other CPE at the location.   For example, in a home with several computers and several different users, each user may use a different ISP for internet communications, and

may even switch between the various ISP's that are coupled to the cable system. When any one of the CPE desire to communicate with another CPE at the home location, traffic is routed through the cable modem,

5   through the cable network and to the ISP selected by the CPE, and routed onto the internet. From the internet, the traffic is routed to the ISP chosen by the destination CPE which routes the traffic back to the cable network and then back to the home network.

10 As can be seen, there are significant external network resources required to route traffic between CPE that are located nearby each other or within a local network.

    Thus, what is needed is a practical, economical,

15 and more efficient apparatus and method for routing traffic between CPE. What is also needed is an improved apparatus and method for routing traffic between CPE that reduces external network requirements. What is also needed is apparatus and method that more

20 efficiently routes traffic between local CPE while properly routing traffic destined for the internet through an ISP associated with the CPE.

SUMMARY OF THE INVENTION

The present invention provides, a local network
router that learns to route IP traffic among customer
premises equipment on a local network rather than
permitting the IP traffic to be routed through a
broadband cable network and selected internet service
provider (ISP) to the internet. The local network
router dynamically generates a routing table from
address resolution protocol (ARP) packets exchanged
between the CPE and the external network. For each IP
data packet received from a CPE that is destined for
another local CPE, the local network router replaces a
default gateway address with an IP address
corresponding with the destination CPE. Accordingly,
network resources for routing traffic are significantly
reduced.

In accordance with the preferred embodiment, a
method of routing IP data packets is provided for an
internal network comprising a plurality of customer
premises equipment (CPE) each having an associated IP
address and machine address. The method comprises the
steps of comparing, for IP data packets received from
the internal network, a destination IP address of a
received IP data packet with IP addresses stored in a
routing table, and when said destination IP address
matches one of said IP addresses stored in said routing
table, replacing a default gateway address of said IP
data packet with a machine address corresponding with
said one IP address from said routing table to create a
revised data packet. The revised data packet is routed
to said internal network for receipt another of said
CPE, said another CPE having said machine address
corresponding with said one IP address.

In one preferred embodiment, the method further
comprises the steps of monitoring IP data packets sent
from the plurality of CPE direct to an external
communication network to detect address resolution
5   protocol (ARP) packets sent from each of said CPE,
extracting said machine address and said IP address
associated with said each CPE from the ARP packet, and
storing said machine address and said IP address in
said routing table that correlates machine addresses
10   and IP addresses with each CPE of said plurality.

Additionally, the method further may comprise the
steps of routing the IP data packets received from the
CPEs to an external network when said destination IP
address does not match one of said IP addresses stored
15   in said routing table, and routing IP data packets
received from the external network directly to the
internal network.

In another embodiment, the present invention
provides a router for use in an internal network. The
20   internal network comprises a plurality of customer
premises devices coupled to the router and a cable
modem coupling the router with an external network.
The router comprises a controller for monitoring IP
data packets sent from the plurality of CPE direct to
25   the external communication network to detect address
resolution protocol (ARP) packets sent from each of
said CPE and extracting a machine address and an IP
address from the ARP packet, and a memory for storing
said machine address and said IP address in a routing
30   table that correlates machine addresses and IP
addresses with each CPE of said plurality. The
controller, for each IP data packet received from each
CPE, compares a destination IP address of said IP data
packet with the IP addresses stored in said routing

table, and when said destination IP address matches one of said IP addresses stored in said routing table, replaces a default gateway address of said IP data packet with said machine address corresponding with said one IP address from said routing table to create a revised data packet, and places said revised data packet onto an internal network for receipt by one of said CPE, said one CPE having said machine address corresponding with said one IP address.

In one preferred embodiment, the router additionally comprises first and second interfaces coupled with the controller. The first and second interfaces provide Ethernet connectivity with networks external to said router. The first interface is coupled to said internal network, and the second interface is coupled to said cable modem for communicating with the external network.

Brief Description of the Drawings

The present invention is pointed out with particularity in the appended claims. However, a more complete understanding of the present invention may be derived by referring to the detailed description and claims when considered in connection with the figures, wherein like reference numbers refer to similar items throughout the figures, and:

FIG. 1a is a simplified block diagram of a communication network in accordance with a preferred embodiment of the present invention;

FIG. 1b is a simplified functional block diagram of a router in accordance with a preferred embodiment of the present invention;

FIG. 2 is a simplified block diagram of an address resolution protocol (ARP) data packet suitable for use with a preferred embodiment of the present invention;

FIG. 3 is a simplified block diagram of an IP data packet suitable for use with a preferred embodiment of the present invention;

FIG. 4 is a simplified flow chart of a procedure for generating a routing table in accordance with a preferred embodiment of the present invention;

FIG. 5 illustrates a routing table suitable for use with a preferred embodiment of the present invention; and

FIG. 6 is a simplified flow chart of a procedure for routing IP data packets in accordance with a preferred embodiment of the present invention.

The exemplification set out herein illustrates a preferred embodiment of the invention in one form thereof, and such exemplification is not intended to be construed as limiting in any manner.

Detailed Description of the Drawings

     The present invention provides, among other
things, a router and method of routing suitable for use
in local networks and in-home use. In accordance with
the preferred embodiments, the method and router of the
present invention, a plurality of customer premises
equipment (CPE) communicate through a two-way broadband
communication network to an internet service provider
(ISP) to access the internet. Traffic destined for CPE
is contained within the local network of CPEs. A
routing table is dynamically generated by the router
using address resolution protocol (ARP) packets. The
routing table preferably includes the IP addresses and
machine address of all CPE on the local network.
Traffic from any of the CPE on the local network that
is destined for other CPE on the local network is
routed back to the local network. In this way, traffic
between CPE's does not need to routed through the cable
network to the ISP's. On the other hand, traffic from
any of the CPE that is destined for an external network
is routed to the external network.

     FIG. 1a is a simplified block diagram of a
communication network in accordance with a preferred
embodiment of the present invention. Network 100 may
be an in-home network or a local area network (LAN) and
comprises a plurality of customer premises equipment
(CPE) 102, 104, 106 coupled to home router 110. CPE
include any computer type equipment that are assigned
IP addressed from an internet service provider (ISP)
126, 128 or 130. CPE include personal computers, web
tablets and any internet communication devices. Home
router is coupled to a modem which communicates through

an external network 120 to the ISP's. External network
includes cable system head end 122 and various other
cable network communication infrastructure required to
provide its services. In accordance with the preferred
5   embodiment of the present invention, modem 114 is a
cable modem and external network is a broadband two-way
cable television system that provides two-way data
communications in addition to video broadcast services.
Network elements such as CPE, home router 110 and modem
10 114 communicate preferably using standard Ethernet
communication interfaces and data formats.

Each CPE receives an IP addresses from the
external systems DHCP server and communicates over
internet 132 through an particular internet service
15 provider (ISP) selected by the CPE or assigned by the
DHCP server. It should be noted that IP addresses
assigned to any of the CPE are not static and change at
least whenever a new session with an ISP is started.

FIG. 1b is a simplified functional block diagram
20 of a router in accordance with a preferred embodiment
of the present invention. Router 110 comprises
interface 140 for communicating with in-home CPE over
an in-home network, and interface 144 for communicating
with an external network, preferably through cable
25 modem 114 (FIG. 1a). Controller 142 couples interfaces
140 and 144 routing traffic that comprises IP data
packets in accordance with information stored in memory
146. Memory 146 comprises any data storage element for
storing routing instructions such as a routing table.
30 FIG. 2 is a simplified block diagram of an address
resolution protocol (ARP) data packet suitable for use
with a preferred embodiment of the present invention.
ARP data packet 200 comprises Ethernet destination
address field 202, Ethernet source address field 204,

other data fields 206, sender MAC address field 208,
sender IP address field 210, Ethernet target address
field 214 and target IP address field 216. A MAC
address as used herein is the Media Access Control

5   address and refers to the physical or hardware address
of a hardware element. The MAC address also may be the
Ethernet address. An ARP packet is sent by CPE to a
default gateway after a CPE receives it's IP address
from the DHCP process. One purpose of CPE sending the

10   ARP packet is to receive configuration information from
the default gateway. The default gateway is associated
with the CPE's ISP and is designated by target IP
address 216 in ARP packet 200.

Ethernet destination address field 202, for

15   example, is set to all ones to signify a broadcast
address. All Ethernet interfaces on the network
preferably receive the frame. Ethernet source address
field 204 and a 2-bit frame type included in other data
field 206 comprise the rest of the Ethernet header for

20   the packet. The other eight bits of other data field
206 are comprised hardware type fields and an ARP
operations field. Sender hardware address field 208 is
the Ethernet address of the device sending the packet.
This is preferably the same as the information

25   contained in Ethernet source address field 204. Sender
IP address field 210 is the IP address that has been
assigned to the device sending the packet. Target
Ethernet address field 214 is preferably left blank and
is filled in by the system that receives the ARP

30   request. Target IP address field 216 is the IP address
that the sending machine is trying to resolve to a
matching Ethernet address.

FIG. 3 is a simplified block diagram of an IP data
packet suitable for use with a preferred embodiment of

the present invention. IP data packet 300 comprises source MAC address field 302, default gateway MAC address field 304, source IP address field 306, destination IP field 308 and IP data field 310.

5   Source MAC address field 302 is the hardware address of the device sending the packet. Default Gateway MAC field 304 is the Ethernet address of the router residing in a service provider network that acts as the first hop point for the packet. Source IP

10   address field 306 is the IP address assigned to the machine sending the packet. Destination IP address field 308 is the address of the final destination of the data enclosed in the packet from the sending machine.

15   FIG. 4 is a simplified flow chart of a procedure for generating a routing table in accordance with a preferred embodiment of the present invention. In step 402, the CPE receive an IP address as part of the DHCP process described above. This IP address is stored in

20   each CPE, and may change each time the CPE is turned on, or the user selects a new ISP. In step 404, the CPE generates an ARP packet as described above and sends the generated ARP packet to a default gateway associated with the ISP selected for the CPE. In step

25   406, the router, which monitors traffic passing through, identifies the ARP packet and pulls the sender's MAC address and sender's IP address from the ARP packet. Using an ARP packet to identify the sender's MAC address and sender's IP address helps

30   assure the router that it has the current and proper IP address for each CPE.

In step 408, the sender's MAC address and sender's IP address are stored in a routing table of the router for each CPE. In step 410, the IP addresses are

verified in the routing table, preferably on a regular
basis such as every 5 minutes. Step 410 may be
performed by sending a "ping" to each CPE to verify
that the CPE are still operating, or by sending an ARP

5   type packet requesting the CPE to verify it's IP
address.

In step 412, ARP packets from the plurality of CPE
are continually monitored to detect any newly added CPE
or changes in CPE IP addresses. Preferably, steps 406

10 through 410 are repeated for each detected ARP packet.
Accordingly, through the execution of procedure 400,
the router maintains the proper IP addresses of CPE
operating in the in-home network.

FIG. 5 illustrates an example routing table

15 suitable for use with a preferred embodiment of the
present invention. Table 500 comprises MAC addresses
502 and corresponding IP addresses 504 for each CPE 506
of home-network.

FIG. 6 is a simplified flow chart of a procedure

20 for routing IP data packets in accordance with a
preferred embodiment of the present invention. Packet
routing process 600 is performed for all traffic that
is received by the router. In step 602, IP data
packets that are received from CPE on the in-home

25 network are evaluated. The destination IP address in
the IP data packet is compared with the IP addresses of
the routing table. In step 604, when the destination
IP address in the IP data packet does not match an IP
addresses stored in the routing table, step 606 is

30 performed. In step 606, the IP data packet is routed
to the external network. This situation applies to
traffic from the CPE that is not destined for another
CPE located in the home or on the local network. In
reference to FIG. 1, in step 606, IP data packets

received from CPE at router interface 140 (FIG. 2) are transferred directly to router interface 144 (FIG. 2) for receipt by modem 114 (FIG. 1).

In step 604, when the destination IP address in the IP data packet matches an IP addresses stored in the routing table, step 608 is performed. In step 608, the router replaces the default gateway MAC address (filed 304 FIG. 3) in the IP data packet with the Ethernet address from the table that corresponds to the destination IP address in the IP data packet evaluated in step 602. As a result of step 608, a revised data packet is created. In step 610, the revised data packet is placed back on the in-home network or local network for receipt by the appropriate CPE.

In task 612, IP data packets received from an external network are directly transferred to the internal network. In reference to FIG. 1, IP data packets received from modem 114 at router interface 144 (FIG. 2) are transferred directly to router interface 140 (FIG. 2).

Thus, a router and method of routing suitable for use in local networks and in-home use has been described. The method and router of the present invention permit a plurality of customer premises equipment (CPE) to communicate through a two-way broadband communication network to an internet service provider (ISP) to access the internet, while traffic destined for local CPE is contained within the local network of CPEs.

The foregoing description of the specific embodiments will so fully reveal the general nature of the invention that others can, by applying current knowledge, readily modify and/or adapt for various applications such specific embodiments without

departing from the generic concept, and therefore such adaptations and modifications should and are intended to be comprehended within the meaning and range of equivalents of the disclosed embodiments.

5   It is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation. Accordingly, the invention is intended to embrace all such alternatives, modifications, equivalents and variations as fall

10 within the spirit and broad scope of the appended claims.